6.0
GENERAL CONSIDERATIONS FOR RISK ASSESSMENT

A risk-based evaluation requires the consideration and understanding of several factors common to Tiers 1, 2 and 3. These factors include, but are not limited to:

- Development of an exposure model (EM),
- Calculation of risk-based target levels,
- Evaluation of groundwater use,
- Protection of surface water bodies,
- Estimation of representative chemical of concern (COC) concentrations,
- Ecological risk evaluation,
- Consideration of nuisance conditions,
- Evaluation of free product, and
- Activity and use limitations (AULs).

This section briefly discusses each of these factors and their application to the management of releases from UST/AST sites. Several of these factors include policy decisions made by the Groundwater Rule Stakeholders Group and documented in the draft process document (MDNR, 2003).

6.1 DEVELOPMENT OF AN EXPOSURE MODEL

The objective of an EM is to define the exposure pathways that are complete or may reasonably be expected to become complete under current or reasonably anticipated future conditions.

An EM identifies the (i) media of concern, (ii) receptors of concern, (iii) exposure pathways from the impacted media to the receptor, and (iv) routes of exposure. The EM presents a working hypothesis of the manner by which COCs migrate from the source to the **points of exposure (POEs)** where COCs come in contact with the receptors and exposure occurs. For each complete combination of source-pathway-route of exposure identified in the EM, risk-based levels must be developed for each COC (see Table 5-1 for a list of COCs). If migration of the COCs from the source to the receptors (i.e. the pathway) is not possible under current or reasonably anticipated future site use (e.g., due to engineering controls or AULs), the COCs will not cause any exposure. Without exposure there can be no risk. Thus for risk to be present at a site, at least one exposure pathway must be complete (or have a reasonable chance of becoming complete).

An EM is a qualitative evaluation based on information collected during site investigations (refer to Section 5.0). Typically, EMs for three time periods will be developed for each site: (i) current land use, (ii) short-term future land use, such as a period of construction, and (iii) long-term future land use. Consideration of current and future land use ensures that site-specific decisions will be protective of both. At sites where the current and future land use will be the same, EMs for current and future use would be identical.

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Development of an EM requires knowledge of (i) land use, (ii) receptors, (iii) pathways and routes of exposure, and (v) exposure domain(s). Each of these elements is discussed in the following sections.

6.1.1 Land Use

Within the MRBCA process, land use is categorized as (i) residential or (ii) non-residential. Accurately identifying land use is important because target levels depend on the land use. Residential land use results in lower target levels and cleanup to these levels generally allows for unrestricted land use. Prior to issuing a No Further Action (NFA) letter, MDNR will require that certain sites cleaned to non-residential standards have some form of AUL. AULs are further discussed in Section 6.9 and Section 11.

Examples of residential and non-residential land use are presented below:

- **Residential or unrestricted land use –** Includes land uses where persons can be expected to reside for more than 8 hours a day, 7 days a week, such as homes, apartments, hospitals, nursing homes, schools, childcare centers, etc.

- **Non-Residential –** Includes land uses where persons can be expected to be on site less than 10 hours a day and absent on weekends and holidays. Examples include retail facilities, industrial and manufacturing operations, fleet operations, hotels and motels, offices, etc.

(**Note:** When a planned development includes a multi-story building, or mixed use, the presence of a day care facility or apartments on an upper floor does not necessarily mean that the applicable land use is "residential." Reasonable assumptions concerning exposures on the ground floor of the building (and subsurface floors, if such exist) should be used to develop cleanup levels.)

While it is not possible to identify every scenario in this document, the following guidelines are intended to assist in making land use determinations:

6.1.1.1 Determine Current Land Use

Identification of the use of the site and nearby properties is used to define potential on-site and off-site receptors that might be exposed to the COCs. Current land use and associated activities must be identified. Current land use refers to land use as it exists today and can be readily determined by a site visit. Thus there should be no ambiguity about current land use.

A visual, on-site land use survey, which should typically include properties within a 500-foot radius of the tank system, shall be conducted. The survey shall clearly identify the following: schools, hospitals, residences (apartments, single-family homes), buildings with basements, day care centers, churches, nursing homes, and types of businesses.

6.1.1.2 Determine Reasonably Anticipated Future Land Use

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"Reasonably anticipated future use" means future use of a site or facility that can be predicted with a reasonably high degree of certainty given historical use, current use, development or use plans, local government planning and zoning, regional trends and community acceptance. In situations where there is an actual plan for development or redevelopment of a property, it shall be the primary consideration in determining "reasonably anticipated future use" when there is a sufficiently high degree of certainty that the plan will be implemented.

Conclusions regarding reasonably anticipated future (RAFU) use may be different for various properties included in the site conceptual model. However, a conclusion as to whether the RAFU for each property is "residential" or "non-residential" must be clearly presented, and the basis for each conclusion must be documented. The MDNR will be the final decision-maker regarding what the appropriate RAFU is for each property.

Future land use is always uncertain and its determination should be based on available information and good professional judgment. In the absence of definitive long-term development plans, the following factors may be used to determine reasonably anticipated future use:

Local planning and zoning,
City/County development plans,
Current use of adjacent property,
Known future use of adjacent property,
Type and size of streets/highways adjacent to the property,
Existing deed instruments or similar instruments affecting the site and/or adjacent properties,
Building permits,
Financing Plans/Restrictions,
Interviews with current property owners, and
Community acceptance of proposed site development plans.

If an undeveloped parcel is located in a predominantly commercial/industrial area, then consideration of the parcel's future use as non-residential might be appropriate. However, if the setting is more rural or the land use is mixed, absent reliable evidence to the contrary, the undeveloped land should be considered residential.

6.1.1.3 On-site and Off-site Receptors

MRBCA evaluations must consider the impact of COCs to both on-site and off-site receptors. A plume moving off-site might impact multiple land uses and multiple receptors. For example, a plume may have migrated off-site below a residential and a non-residential area. In this case, both land uses have to be considered when developing the EM. For simplification, the following definitions should be used:

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- **On-site**: The property located within the legal property boundaries within which the source of the release is located. This includes soil, groundwater, surface water, and air within those boundaries.

- **Off-site**: Property (ies) located outside the boundaries of the onsite property and on to which COCs associated with the release have or are likely to migrate. This includes soil, groundwater, surface water, and air located off-site.

6.1.2 Receptors

The MRBCA process requires consideration of both human and ecological receptors as discussed below:

6.1.2.1 Human Receptors

All current and future human receptors should be considered. At a minimum, the following human receptors are considered:

- Residential – Child, adult, and age-adjusted individual
- Non-residential Worker – Adult
- Construction Worker – Adult

The age-adjusted individual is one who lives at a site continuously from birth to age 30 (also refer to equations presented in Appendix B).

For residential land use, the lowest of the three target levels for child, age-adjusted, and adult are applicable.

Other human receptors such as visitors or maintenance workers will generally have less exposure than those listed above (due to lower exposure frequency and duration) and, therefore, their exposure and risk need not be quantified. However, if these or other such receptors will be or are known to be on the site for periods exceeding those considered for resident, non-resident worker, or construction worker, such receptors must be evaluated.

6.1.2.2 Ecological Receptors

All sites evaluated under MRBCA must be screened for the presence of ecological receptors and/or their habitats, except for those sites where initial sampling data indicates that COC concentrations are below the default target levels (DTLs) and the site poses no obvious threat to ecological receptors. At certain sites where exposure to wetlands, sensitive environments, wildlife, threatened and/or endangered species, or other ecological receptors is complete, a quantitative ecological risk evaluation may have to be completed. The level of cleanup at such sites should be based on the lower of the target levels for human and ecological receptors. The MRBCA tiered ecological risk evaluation process is further discussed in Section 6.6.

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As appropriate, surface water bodies should be evaluated to determine potential impacts of discharging groundwater or surface runoff from the release site. Such an evaluation might require information on the location, flow rates, depth, flow direction, and designated beneficial uses of specific surface water bodies. Refer to Section 5.10 and 6.4 for further information.

6.1.2.3 Utilities

On-site and off-site underground utilities and, specifically, their ability to serve as petroleum contamination conduits, must be evaluated. Adverse impacts to utilities might include degradation of water and sewer lines; vapors in storm and sanitary sewers; damage to outer coatings of gas lines; damage to plastic lines, and damage to buried phone and electrical lines due to contact with chemicals. Utility evaluations are of particular importance at sites where utilities may come in contact with free product for an extended period of time. Refer to Section 5.4.3 for further information regarding the evaluation of utilities.

6.1.3 Human Exposure Pathways and Routes of Exposure

A receptor comes in contact with COCs if a complete exposure pathway exists under current or future land use conditions. For a pathway to be complete, there must be a (i) chemical source, (ii) mechanism by which the chemical is released, (iii) medium through which the chemical travels from the point of release to the receptor location, and (iv) a route of exposure by which the chemical enters the receptor's body and potentially causes adverse health effects.

Commonly encountered exposure pathways that must be considered are discussed below. For each complete pathway, the MRBCA process requires (i) collection of sufficient data to estimate the representative concentrations of COCs for each pathway (except for surficial soil in a residential setting where the maximum COC concentrations are used), and (ii) the comparison of representative (or maximum) concentrations with target levels for the corresponding pathway.

6.1.3.1 Pathways for Inhalation

For the inhalation pathway, chemical intake occurs indoors and outdoors at a site via the inhalation of vapors. Depending on the toxicity of the chemical, unacceptable exposures via the inhalation pathway might occur at concentrations below the odor threshold levels (i.e., receptors might be unaware of their exposure). If the source of these vapors is volatile chemicals in soil and/or groundwater, their migration through the capillary fringe, unsaturated zone, and cracks in the floor/foundation to indoor or outdoor air must be evaluated. As discussed in Section 5.4.3, the potential for utilities to act as a conduit for vapors must also be evaluated. Relative to outdoor inhalation, indoor inhalation is the "risk driver," hence outdoor inhalation is not quantitatively evaluated except when there is or could be direct contact with soil (e.g., construction worker).

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To quantitatively evaluate the indoor inhalation pathway, use the following approach (also refer to Appendix C, Figure C-1):

- **Tier 1 risk assessment:** Compare representative soil and groundwater concentrations to the applicable soil and groundwater target levels in Tables 7-1 through 7-6. Soil vapor sampling may be conducted at Tier 1.[1] When conducted, the sampling results shall be compared to the Tier 1 soil vapor RBTLs found in Tables 7-1 (residential land use) or 7-2 (non-residential land use), whichever is applicable. NOTE: If soil vapor sampling is done, the measured soil vapor concentrations *must* be used to evaluate the indoor inhalation risk in lieu of using soil and groundwater data to analyze this risk.

  Tier 2 risk assessment: Calculate Tier 2 SSTLs for residential and/or non-residential use, as appropriate for each impacted property.

  If soil vapor sampling was not conducted as part of Tier 1, determine whether to do it as part of the Tier 2 risk assessment.[1]

  How one assesses indoor inhalation risk at Tier 2 depends on whether soil vapor sampling is done. If soil vapor sampling is *not* done, compare representative concentrations of COCs in soil and groundwater to the calculated Tier 2 inhalation target levels to determine whether there is an indoor inhalation risk. If soil vapor sampling *is* done, the measured soil vapor concentrations *must* be used to evaluate the indoor inhalation risk in lieu of using soil and groundwater data to analyze this risk; use appropriate representative concentrations of measured soil vapor samples.

- **Tier 3 risk assessment:** Several options are available, each of which requires the development of a work plan and its approval by MDNR prior to implementation. Two examples are presented below:

  - Option 1: Use of measured soil, groundwater, or soil vapor concentrations with alternative models to estimate target risk due to indoor inhalation,

  - Option 2: Indoor air concentrations may be measured and compared with indoor air target levels. However, due to several difficulties associated with accurately determining whether and to what extent COCs detected in indoor air are attributable to soil and/or groundwater impacts, direct measurement of indoor air is seldom conducted.

6.1.3.2 Pathways for Surficial Soils (0 - 3 feet bgs)

Surficial soils are defined as soils extending from the surface to three feet below ground

[1] Refer to Appendix C for a discussion of soil vapor monitoring and development of SSTLs for soil vapor.

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Step 2: Calculate Tier 2 soil vapor SSTLs, conduct soil vapor monitoring, and compare the representative measured soil vapor concentrations to the Tier 2 soil vapor SSTLs.

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Deleted: In all the above cases, mathematical models are used to estimate the soil, groundwater, or soil vapor concentrations protective of indoor inhalation or to estimate the risk from measured soil, groundwater or soil vapor concentrations. Refer to Appendix C for a discussion of soil vapor monitoring and development of SSTLs for soil vapor.¶

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surface. The exposure pathways associated with impacted surficial soil include:

- Leaching to groundwater and potential use of groundwater,
- Leaching to groundwater and subsequent migration to a surface water body, and
- Ingestion of soil, dermal contact with soil, and outdoor inhalation of vapors and particulates emitted by surficial soils.

6.1.3.3 Pathways for Subsurface Soils (>3 feet bgs to the water table)

Subsurface soils are defined as soils from three feet below ground surface to the water table or to bedrock, whichever occurs first. Exposure pathways associated with subsurface soils include:

- Indoor inhalation of vapor emissions,
- Leaching to groundwater and potential use of groundwater, and
- Leaching to groundwater and subsequent migration to a surface water body.

It is important to note that no distinction is made between the surface and subsurface soil for the construction worker. Instead, dermal contact, accidental ingestion, and outdoor inhalation of soil vapors and particulates from soils are considered complete pathways up to the typical depth of construction.

6.1.3.4 Pathways for Groundwater

Potentially complete exposure pathways for impacted groundwater include:

- Volatilization and upward migration of vapors from groundwater and potential indoor inhalation of vapor emissions,
- Ingestion of water if the groundwater is a current or future source of drinking water,
- Dermal contact with groundwater, and
- Migration to a surface water body and potential impacts to surface waters.

6.1.3.5 Pathways for Surface Water and Sediments

Depending on the use designation of the surface waters, potentially complete routes of exposure for surface water include:

- Ingestion of surface water,
- Contact with surface water during recreational activities (ingestion, inhalation of vapors, and dermal contact),
- Ingestion of fish, and
- Contact with (accidental ingestion and dermal contact with) sediments.

In addition, ecological effects must be considered if surface water impacts are present.

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Each of the above routes of exposure for surface water and sediments must be considered as part of the exposure assessment. If all of these routes of exposure are considered incomplete, no quantitative evaluation is necessary. Refer to Section 6.4 for information regarding the quantitative evaluation of these pathways.

6.1.3.6 Other Pathways

At some sites, other routes of exposure might be significant. These include, but are not limited to, exposure due to (i) ingestion of produce grown in impacted soils, (ii) exposures associated with use of groundwater for irrigation purposes, or (iii) use of groundwater for industrial purposes.

At UST/AST sites, these routes of exposure are likely to be significant only in rare cases and will be evaluated at Tier 3.

6.1.4 Exposure Domain

A key part in the development of an EM is the determination of the size and location of the exposure domain for each pathway, route of exposure, and receptor. The exposure domain is the portion of the total impacted area that contributes to the receptor's exposure via a specific pathway and route of exposure. The exposure domain can vary with the receptor and the route of exposure.
The following three examples may help clarify the concept of the exposure domain:

Example 1: For exposures within an existing building by indoor inhalation of vapors from subsurface soil, the exposure domain would be the volume of soil within the footprint of the building that contributes vapors to the indoor air.

Example 2: For direct contact with surficial soil, the exposure domain would be the area of impacted surficial soil that the receptor might come in contact with.

Example 3: For the protection of groundwater, the domain would be the volume of soil that could contribute chemicals to the groundwater plume via leaching and infiltration.

For each receptor and each complete route of exposure, the exposure domain must be determined. Concentrations measured within each exposure domain must be used to estimate the representative concentrations for each complete pathway, as discussed in Section 6.5 (except, as noted above, maximum COC concentrations are used for the evaluation of surficial soil in a residential setting).

6.2 CALCULATION OF RISK-BASED TARGET LEVELS

Within the MRBCA process, risk-based target levels include:

- Default target levels (DTLs),
- Tier 1 risk-based target levels (RBTLs),
- Tier 2 site-specific target levels (SSTLs), and

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- Tier 3 SSTLs.

Note that the DTLs are the lowest of the Tier 1 RBTLs for soil and groundwater.

Also refer to Appendix B (Sections B.8 and B.9) for a discussion of the target levels for lead and target levels when LNAPL is present on groundwater.

Calculation of the above target levels requires quantitative values of (i) target risk, (ii) chemical-specific toxicological factors, (iii) receptor-specific exposure factors, (iv) fate and transport parameters, (v) physical and chemical properties of the COCs, and (vi) mathematical models. Each of these is discussed below (also refer to Appendix B):

6.2.1 Target Risk Level

For carcinogenic effects, risk is quantified using **individual excess lifetime cancer risk (IELCR),** a value that represents an increase in the probability of an individual developing cancer due to exposure to a chemical via a specific route of exposure. For petroleum tank sites, the target IELCR for each COC and route of exposure is 1×10^{-5}.

For non-carcinogenic effects, risk is quantified using a **hazard quotient (HQ)** that represents the ratio of the estimated dose for a chemical via a specific route of exposure to the reference or allowable dose. At petroleum UST/AST sites, the target HQ for each COC and each route of exposure is 1.0.

Due to the limited number of COCs at typical petroleum UST/AST sites, the additivity of risk due to multiple chemicals and multiple routes of exposure is not considered.

6.2.2 Quantitative Toxicity Factors

The toxicity of chemicals is quantified using slope factors for chemicals with carcinogenic adverse health effects and reference doses for chemicals that cause non-carcinogenic adverse health effects. Toxicity values may differ for the inhalation, dermal and ingestion pathways.

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Toxicity values for the COCs are presented in Appendix B. MDNR requires that the most recent toxicity values recommended by the US EPA be used. For a Tier 3 risk assessment, values other than those presented in Appendix B may be used if their use can be adequately justified and the values are approved by MDNR.

6.2.3 Exposure Factors

Exposure factors describe the physiological and behavioral characteristics of the receptor and are typically estimated based on literature rather than site-specific measurements. Default exposure factors for calculating Tier 1 and Tier 2 target levels are presented in Appendix B. For a Tier 3 risk assessment, a combination of site-specific and default exposure values may be used if their use can be adequately justified and the values are approved by MDNR.

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6.2.4 Fate and Transport Parameters

Fate and transport parameters are necessary to estimate the target levels for the indirect routes of exposure. These factors characterize the physical site properties (such as depth to groundwater, soil porosity, and infiltration rate) and building characteristics (such as the height of a building and the air exchange rate). For calculating DTLs and Tier 1 RBTLs, MDNR has selected the conservative default fate and transport values presented in Appendix B. For Tier 2, a combination of site-specific and default values may be used. However, all the values used must be justified based on site-specific considerations.

6.2.5 Physical and Chemical Properties

The development of target levels requires the physical and chemical properties of the COCs that are listed in Appendix B. Several of the physical and chemical properties are experimentally determined; hence their values are not exact and include a certain amount of variability. MDNR requires the use of values presented in Appendix B for all tiers, unless there are justifiable reasons to modify these values. The use of different values would be allowed only under a Tier 3 risk assessment and upon MDNR's approval of a work plan.

6.2.6 Mathematical Models

Two types of models, or equations, namely the (i) uptake equations, and (ii) fate and transport models, are required to calculate the target levels. For the calculation of DTLs, Tier 1, and Tier 2 target levels, MDNR has selected the following fate and transport models:

Indoor Inhalation of Volatile Emissions from Soil and Water: This pathway requires (i) an emission model and (ii) an indoor air mixing model. These models are combined together and included in the Johnson and Ettinger Model (US EPA, 2001) and are used in the MRBCA process. Note that the model used in the MRBCA process does not include advective transport of vapors.

Surficial Soil Outdoor Inhalation (construction worker only): This pathway requires (i) an emission model for vapors, (ii) an emission model for particulates, and (iii) an outdoor air mixing model. The vapor emission model used is based on the volatilization model developed by Jury et al. (1984) for an infinite source. The particulate emissions model is based on Cowherd's model, and the outdoor air mixing model is a simplified form of the Gaussian Dispersion model. These models are presented in the Soil Screening Guidance Document (US EPA, 1996).

Leaching to Groundwater: This pathway requires (i) equilibrium conversion to convert soil concentrations to leachate concentration, and (ii) mix the leachate with the regional groundwater. The equilibrium conversion model is that found in EPA's Soil Screening Guidance Document (US EPA, 1996). Summer's model is used for mixing of the

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leachate with the groundwater.

Horizontal Migration in Groundwater: Domenico's steady-state infinite source model is used to quantify the downgradient migration of chemicals. For Tier 2 risk assessments, a biodegradation rate may be used if it can be justified based on site-specific conditions and has the prior approval of MDNR.

Unsaturated Zone Transport: For the calculation of Tier 2 values, the following dilution attenuation factors (DAF) will be used:

Depth to groundwater of less than 20 feet,	DAF = 1
Depth to groundwater 20-50 feet,	DAF = 2
Depth to groundwater > 50 feet,	DAF = 4

DAF represents the reduction in the concentration, due to the combined influence of natural attenuation processes, of the leachate as it migrates from the "source" to the bottom of the unsaturated zone (typically the water table). A DAF of 1 indicates that there is no reduction in concentration. A DAF of 2 implies that the concentration of the leachate reduces by a factor of 2 as the leachate migrates from the "point of generation" to the water table. The DAF factors presented above are empirical. For a Tier 3 risk assessment, unsaturated zone fate and transport models may be used to estimate the unsaturated DAF, with the approval of MDNR.

6.3 EVALUATION OF GROUNDWATER USE

Within the MRBCA process, all current and reasonably anticipated future use of groundwater must be protected. Impacts to groundwater and potential exposures via the groundwater ingestion pathway are of significant concern in Missouri since several areas of the state obtain their drinking water from groundwater sources. The evaluation process and groundwater protection measures are intended to be used in cases where groundwater has been impacted or is likely to be impacted by a site-specific petroleum release. This process has the following objectives:

- To protect all current and reasonably likely future domestic use of groundwater,
- To provide a rational basis for incorporating site-specific characteristics into the determination of groundwater target levels, and
- To facilitate the development of properties based on reasonable expectations for groundwater cleanup.

A key consideration in developing risk-based groundwater target levels is whether the groundwater use pathway is complete under current or future conditions. The process used to make this determination is shown in Figure 6-2 and discussed below. Note that this determination is required for all groundwater zones at and in the vicinity of a site.

Figure 6-2 focuses on the domestic use of groundwater. As a part of this step, other groundwater uses (e.g., cooling water, industrial process water, etc.) must also be

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identified.

Evaluations of groundwater use must be in strict accordance with Figure 6-2 and each applicable element of Figure 6-2 must be clearly addressed in a risk assessment report. MDNR recommends these conclusions be presented in the same order as the evaluation criteria in Figure 6-2.

At some sites, the zone of groundwater contamination and the zone utilized for domestic use might not be the same. Therefore, as shown in Figure 6-2, the first step in determining whether the groundwater use pathway is complete is to identify all groundwater zones beneath a site and whether they are interconnected.

6.3.1 Current Conditions

The current groundwater use pathway is considered complete if (i) there are existing wells near the site, and (ii) the wells are reasonably likely to be impacted by COCs.

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The existence of wells near the site is determined based on a water well search that might range, at a minimum, from a search of the State of Missouri well database to a door-to-door survey. The level of effort will depend on site-specific considerations. For example, in urban areas having a municipal water supply, a door-to-door survey might not be necessary whereas in rural areas where groundwater is the primary source of water, a door-to-door survey might be necessary. The survey shall identify all private water wells within a one-quarter (¼) mile radius and all public water supply wells within a one-mile radius of the tank system.

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Whether the wells have a reasonable probability of impact depends on the distribution and migration potential of COCs relative to the groundwater zone or zones of interest. Whether COCs will reach a groundwater zone of interest depends on the volume of the release and the properties of the subsurface soil and bedrock. Once COCs impact groundwater, whether they have a reasonable probability of reaching a point of exposure, (such as an existing well), depends on hydrogeological conditions including, but not limited to: (i) groundwater flow direction, (ii) distance to well, (iii) the zone where the wells are screened, (iv) casing of the well, and (v) biodegradability and other physical/chemical properties of the COCs. Depending on site-specific conditions, a fate and transport model may be used to evaluate the potential impacts (generally, such modeling would be a Tier 3 activity).

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6.3.2 Future Conditions

All groundwater zones beneath and/or in the vicinity of the site that could potentially be targeted in the future for the installation of domestic water wells must be identified. For the purposes of this analysis, the saturated zone can be divided into multiple "layers", but all layers within the saturated zone must be considered[2].

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For each zone, determining whether the future groundwater use pathway is complete or

[2] It must be assumed that all zones currently utilized will be utilized in the future as well.

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likely to be complete is based on consideration of the following factors:

Determination of Sufficient Activity and Use Limitations (AUL): If there is an AUL in place that essentially eliminates any reasonable probability that a groundwater zone under consideration will ever serve as a future source of domestic water, no further evaluation of the groundwater use (domestic consumption) pathway is required for that groundwater zone.

Suitability for Use Determination: For groundwater to be considered a viable water supply source, total dissolved solids (TDS) and yield criteria must be met. Groundwater containing less than 10,000 mg/L total dissolved solids shall be considered as having sufficient natural quality to serve as a potential source of domestic water.

Groundwater zones capable of producing a minimum of 1/4 gallon per minute or 360 gallons per day on a sustained basis shall be considered as having sufficient yield to serve as a potential source of domestic water. The yield of a bedrock aquifer should be based on the measured or calculated production of a 6-inch drilled well that penetrates the lesser of either the full saturated thickness of the aquifer or the uppermost 200 feet of the saturated zone. The yield of a low yield unconsolidated (glacial drift or alluvial) aquifer should be based on the measured or calculated production of a 3-ft diameter augered or bored well that penetrates the lesser of either the entire saturated thickness of the aquifer or the uppermost 50 feet of the saturated zone. Refer to Appendix D for further guidance on determining whether a particular zone should be considered as a potential domestic water source.

Groundwater zones meeting both TDS and yield criteria shall be considered as suitable for domestic use.

Sole Source Determination: If the groundwater zone being considered is the only viable source of water at or in the vicinity of the site (groundwater or surface water), then one must assume that future domestic use is reasonable (irrespective of TDS or yield considerations), and evaluate whether the zone is likely to be impacted by COCs from the site. Determining the availability of alternative water supplies must include consideration of other groundwater zones, municipal water supply systems, and surface water sources. Note, however, in accordance with Figure 6-2, if the groundwater zone being evaluated is determined to be suitable for use, the sole source determination step of the evaluation is not relevant.

Probability of Future Use Determination: The probability that a groundwater zone could be used as a future source of water for domestic consumption shall be evaluated based on consideration of the following factors:

- Current groundwater use patterns in the vicinity of the site under evaluation,
- Suitability of use (e.g., TDS, yield),
- Availability of alternative water supplies,
- AULs,

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- Urban development considerations for sites in areas:
  - of intensive historic industrial/commercial activity,
  - located within metropolitan areas that had a population of at least 70,000 in 1970, and
  - having groundwater zones in hydraulic communication with such industrial/commercial surface activity.
- Aquifer capacity limitations (ability to support a given density of production wells).

The above factors will be evaluated on a "weight of evidence" basis: the weight that a single factor will be given in determining the probability of future use will vary based on site-specific considerations, including the durability of the AUL.

The degree to which AULs will affect the determination will depend on the attributes of the specific AUL. If the attributes of the AUL are not appropriate, the groundwater zone might remain a reasonably likely future domestic water source, despite the existence of the AUL. If the AUL does not explicitly apply to a specific water bearing zone that meets each of the following criteria, that groundwater zone will generally be determined as having a reasonable probability of future use:

(i) The zone is the highest quality groundwater resource (considering both yield and natural quality) in the hydrostratigraphic column.
(ii) The zone has sufficient quantity and yield to serve as a primary component of the regional water supply.
(iii) The zone has no widespread groundwater impacts associated with historic human activity in the vicinity of the site (excluding groundwater impacts associated with the specific site).

The above is only one set of circumstances that would result in a determination that the groundwater zone has a reasonable probability of future use as a domestic water supply. Other circumstances might result in the same determination.

Each groundwater zone that has a reasonable probability of future use as a domestic water supply shall be carried forward to the "probability of impact" determination discussed below.

Probability of Impact Determination: The probability that the site could impact the water quality in a groundwater zone having a reasonable probability of serving as a future source of domestic water shall be evaluated. The evaluation shall consider the nature and extent of contamination at the site, site hydrogeology including the potential presence of karst features, contaminant fate and transport factors and mechanisms, and other pertinent variables. For the purpose of evaluating potential site impacts to groundwater zones that could serve as future water supply sources, the potential impact shall be evaluated at the nearest down-gradient location that could reasonably be considered for installation of a groundwater supply well. In the absence of durable AULs, the nearest location might be on the site itself.

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6.3.3 Evaluation of Complete Pathway

If the groundwater use pathway is deemed to be complete under current or future conditions, it must be quantitatively evaluated as follows:

Step 1: Identification of the critical POE. The POE shall be the nearest down-gradient three-dimensional location that could reasonably be considered for installation of a groundwater supply well. Note that the POE need not necessarily be an actual existing well; the POE could be a hypothetical well.

Step 2: Determination of target levels at the POE. For chemicals that have maximum contaminant levels (MCLs), the target level at the POE will be the MCLs. For chemicals that do not have MCLs, the target levels will be the risk-based calculated value that assumes groundwater ingestion and indoor inhalation of vapors based on water use. Note that the indoor inhalation of vapors based on water use pathway will be considered only for volatile COCs (refer to Figure 6-3).

Step 3: Identification of point of demonstration (POD) wells and calculation of target levels at the POD. POD wells are located between the source and the POE for the purpose of monitoring COC concentrations in groundwater as a means of protecting against exceedances at the POE. Risk-based target concentrations will be developed for the POD using appropriate fate and transport models and site-specific parameters as explained in Appendix B. If the POE is within an area where COCs in groundwater currently exceed applicable target levels, a POD is not relevant. Only if the POE is outside the area where COCs in groundwater exceed applicable target levels is a POD relevant.

Step 4: Calculation of soil COC concentrations in the area of release. Risk-based target levels for soil and groundwater source areas are calculated as indicated in Appendix B.

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Thus the quantitative evaluation of this pathway requires the calculation of target levels at the (i) POE, (ii) POD, and (iii) soil point and area of release. The soil point and area of release concentrations must be compared with representative concentrations at the site while the POE and POD are to be compared to COC concentrations at those points. If the POE is within the groundwater COC plume, target levels for the POD and groundwater source are not applicable.

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6.4 SURFACE WATER AND STREAM PROTECTION

Potential impacts to streams and other surface water bodies from a release must be evaluated and surface water quality protected as per 10 CSR 20-7.031. Sampling for COCs in surface water bodies will be necessary when COC migration is known or suspected to adversely affect a surface water body.

6.4.1 Protection of Streams

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Protection of streams requires the determination of (i) stream classification, (ii) identification of the use designations of the stream, (iii) estimation of allowable COC concentrations in the stream, (iv) determination of stream 7Q10, and (v) calculation of allowable COC concentrations at various locations within the stream and the groundwater plume. The latter include:

- Instream COC concentrations at the downstream edge (and beyond) of a mixing zone (C_{sw}),
- Instream COC concentrations at the downstream edge (and beyond) of the zone of initial dilution, if applicable (C_{zid}),
- Groundwater COC concentrations at the point of discharge of the groundwater plume to the surface water body (C_{gw}),
- Groundwater COC concentrations at points of demonstration at different distances between the source and the point of discharge (C_{pod}), and
- Soil COC concentrations at the source area soils (C_{soil}).

The locations of these various points are schematically shown in Figure 6-4. Depending on site-specific conditions, sampling for COC concentrations at one or more of these locations may be necessary.

The procedure for protection of streams and surface waters is shown in Figure 6-5 and discussed below:

Step 1: Determine stream classification: As per 10 CSR 20-7.031(1)(F), streams in Missouri are classified as Class C, Class P, or P1 waters. Stream classification applies to specific reaches of a stream and not necessarily to the entire stream length. Classification of streams and the length of the classified segment can be found in Table H of 10 CSR 20-7.031. Streams not included in Table H are unclassified (Class U) and have no assigned designated uses.

Step 2: Determine the beneficial use designation(s) of the stream: As per 10 CSR 20-7.031(1)(C), beneficial uses of a stream include one or more of the following:

- Irrigation (IRR),
- Livestock & wildlife watering (LWW),
- Protection of warm water aquatic life and human health – fish consumption (AQL),
- Cool water fishery (CLF),
- Cold water fishery (CDF),
- Whole body contact recreation (WBC),
- Boating and canoeing (BTG),
- Drinking water supply (DWS), and
- Industrial (IND).

Beneficial use designations for classified streams are tabulated in Table H of 10 CSR 20-

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7.031. A stream may have multiple beneficial use designations, in which case all beneficial uses must be identified.

Step 3: Determine stream water quality criteria: Stream water quality criteria depend on the beneficial use designation(s) of the stream and can be found in Table A of 10 CSR 20-7.031. For the COCs relevant to petroleum storage tank sites, the criteria are also presented in Table 6-1. For streams with multiple beneficial uses, select the most protective applicable criteria. For metals, the criteria for the protection of aquatic life depend on the hardness of water. For specific water quality criteria values, refer to 10 CSR 20-7.031, Table A.

If chemicals for which water quality criteria are not available are present at a site, contact MDNR's Water Protection Program (WPP) for further guidance.

For Class C and Class P or P1 streams, water quality criteria must be met at the downstream edge of the mixing zone. For unclassified streams, applicable water quality criteria must be met at the point of groundwater discharge to the stream.

Step 4: Determine 7Q10 and groundwater discharge: The 7Q10 low-flow of a stream is the average minimum flow for seven consecutive days that has a probable recurrence interval of once-in-ten years. Estimation of 7Q10 shall follow current industry practices as included in USGS and USEPA literature. The lowest value of 7Q10 that can be used as a default value for a Tier 1 risk assessment that includes Class C and Class P or P1 streams is 0.1 cubic feet per second (cfs). Unclassified streams have a default 7Q10 value of 0.0 cfs. Also, the volume of impacted groundwater discharging into the stream must be determined. This determination is based on the dimensions of the plume at the point of discharge and an average Darcy velocity at the point of discharge. Specific equations are included in Appendix B. For flow-regulated streams, contact MDNR's WPP for the estimation of 7Q10.

Step 5: Estimate concentrations at the point of discharge: The concentrations at the point of discharge can be estimated using mass balance considerations. For streams with a 7Q10 of 0.1 cfs or greater, the stream flow to be used in the calculation is 0.25 of the 7Q10 flow calculated in Step 4. The specific equations are included in Appendix B.

Step 6: Estimate groundwater and soil concentrations: Applicable COC concentrations for soil and groundwater can be back-calculated using the concept of DAFs. The specific equations, a combination of the Summer's Model and the Domenico's model, are presented in Appendix B.

The soil and groundwater COC concentrations discussed above apply to the protection of surface water. Other routes of exposure from groundwater, such as inhalation of volatiles and ingestion of groundwater, must also be evaluated as part of the process. Cleanup criteria based on these routes of exposure may result in allowable COC concentrations lower than those protective of a surface water body.

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Step 7: Other considerations: In addition to specific water quality criteria, general water quality criteria must be met in waters of the state at all times, including mixing zones. General water quality criteria are discussed in 10 CSR 20-7.031(3).

In addition to meeting chronic water quality criteria at the downstream edge of the mixing zone, acute water quality criteria must be met as per the following:

- For Class C and unclassified streams, the acute criteria must be met at the point of discharge.
- For Class P and P1 streams, the acute criteria must be met at the edge of the zone of initial dilution and throughout the mixing zone.
- For an unclassified stream that flows into a classified stream or becomes a classified stream downstream of the point of discharge, the acute criteria must be met at the point of groundwater discharge to the unclassified stream.

6.4.2 Protection of Lakes

For lakes the above considerations also apply. Note that the mixing zone shall not exceed one-quarter (¼) of the lake width at the discharge point or one hundred feet (100 ft) from the point of discharge, whichever is less. Also, a zone of initial dilution is not allowed in lakes.

6.5 ESTIMATION OF REPRESENTATIVE CONCENTRATIONS

Application of the MRBCA process results in target levels for each complete pathway identified in the EM and each associated COC. For site-specific risk management decisions, these target concentrations must be compared with appropriate representative concentrations. Note, however, that for the direct contact with surficial soil pathway at a residential site, the target levels are compared with the maximum surficial soil COC concentrations. In addition, representative concentrations are not determined when comparing COC concentrations to the DTLs. Rather, maximum COC concentrations are used in this comparison.

Note that representative concentrations must be calculated for each complete route of exposure. Since there may be several complete pathways at a site, several representative concentrations, one for each complete pathway, must be calculated. If the maximum media-specific concentration of a COC for a specific pathway does not exceed the target level for that pathway, a representative concentration need not be calculated for that pathway.

Calculation of representative concentrations is further discussed at Appendix E. A brief summary is presented in Table 6-2.

6.6 ECOLOGICAL RISK EVALUATION

A key objective of the MRBCA process is to manage sites so that they are protective of

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both human health and the environment, the latter including all non-human organisms and their habitat (i.e., ecological receptors). Exposures to ecological receptors must be evaluated to ensure such receptors are adequately protected.

A three tiered process has been developed to incorporate ecological protection into the MRBCA process. The ecological protection process includes the following:

Except at sites where initial investigations indicate that COC concentrations are below the DTLs and the site poses no obvious threat to ecological receptors, a Tier 1 ecological evaluation must be performed at every site to identify whether any ecological receptors or habitat exist at, adjacent to, or near the site. This evaluation is accomplished through completion of Ecological Risk Assessment Checklist #1 (Attachment A located at the end of Section 5), consisting of eight questions. MDNR intends for this checklist to be a qualitative evaluation that can be completed by an experienced environmental professional who is not necessarily a trained biologist or ecologist. The checklist is designed such that, if the answer to all the questions is negative, no further ecological evaluation is necessary and there are no ecological concerns at the site.

A positive answer to any one of the eight questions in the checklist implies that a receptor or a habitat exists on or near the site and, therefore, further evaluation is warranted. If any of the questions in checklist 1 are answered in the affirmative, a second checklist, Checklist #2 (Attachment B located at the end of Section 5), consisting of seven questions, must be completed. The intent of this checklist is to determine whether any complete pathways to the receptor(s) identified in Checklist #1 exist. If the answer to all the questions is negative, the implication is that, even though a receptor exists on or near the site, a complete pathway to the receptor(s) does not exist and, therefore, there are no ecological concerns at the site. If the answer to one or more of the seven questions is positive, a Tier 2 risk assessment may be necessary to determine whether contamination at the site being evaluated poses an unacceptable risk to ecological receptors.

A Tier 2 ecological evaluation will include comparison of site-specific COC concentrations that might reach an environmental receptor to existing literature values. Examples of existing sources of these values include, but are not limited to, the following:

- Oklahoma's Water Quality Standards as presented in Title 785: Oklahoma Water Resources Board, Chapter 45. Oklahoma's Water Quality Standards. Subchapter 5. Surface Water Quality Standards. Part 3. Beneficial Uses and Criteria to Protect Uses. Acquired from the Oklahoma Water Resources website http://www.state.ok.us/~owrb/wq/StandardsNew_final.htm.

- Ecotox Thresholds (ETs) as presented in ECO Update, US EPA, Office of Solid Waste and Emergency Response. Publication 9354.0-12FSI, EPA 540/F-95/038, PB95-963324. January 1996. Officer of Emergency and Remedial Response Intermittent Bulletin Volume 3, Number 2.

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- ORNL Values as presented in Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota: 1996 Revision. ES/R/Tm-96/R2. Suter II and C.L. Tsao. June.

If comparison of site-specific soil, groundwater, surface water, or sediment values indicates that applicable values are exceeded, available options include: (i) performance of a Tier 3 ecological evaluation or (ii) use of the applicable literature values as cleanup goals. If the latter option is chosen, a corrective action plan (CAP) must be submitted, approved by MDNR, and implemented in a timely manner.

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A Tier 3 ecological evaluation will include a detailed site-specific evaluation as per the current U.S. EPA guidance on performing risk evaluation (for instance, EPA's April 1998, Guidelines for Ecological Risk Assessment, EPA/630/R-95/002F). A Tier 3 risk assessment will require the development of a site-specific, detailed work plan and approval of MDNR prior to its implementation.

6.7 CONSIDERATION OF NUISANCE CONDITIONS

In addition to the evaluation of human health and ecological risks, any nuisance conditions that exist, such as objectionable taste or odor in groundwater, aesthetic problems with resurfacing groundwater, and odor from soils remaining in place, must be documented and reported to MDNR.

6.8 EVALUATION OF LIGHT NON-AQUEOUS PHASE LIQUID (LNAPL)

Detection of the mobile phase of LNAPL, known as free product, must trigger a response sufficient to achieve the following objectives:

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1. Free product must not be present at levels that would cause explosive conditions to occur at or near the site (see 10 CSR 26-2.075),
2. The extent of free product in the environment shall be fully delineated,
3. Dissolution of and volatilization from LNAPL must not generate dissolved phase or vapor phase concentrations that result in unacceptable human or ecological risk,
4. Free product must no longer be migrating, and
5. Free product shall be removed to the maximum extent practicable.

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When data collected under the MRBCA process shows that these goals have been achieved, no further evaluation or removal of free product will be required. In some cases, provided all other requirements are met, MDNR may issue a NFA letter for a site even though free product remains.

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A brief discussion of each of these objectives is presented below.

6.8.1 Protection against Explosive Risk

In certain circumstances, the presence of free product can pose a risk of explosion due to

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vapor migration and accumulation. At sites where free product is present, vapor monitoring must be conducted in the area immediately above and within 100 feet of the known extent of free product. Such monitoring must use monitoring equipment capable of detecting contaminants associated with the specific type of free product found at a site at concentrations equal to or less than 10 percent of the lower explosive limit (LEL) of each volatile component of the free product. Vapor concentrations must be monitored at all utilities, subsurface and surface structures, and any other enclosed spaces found immediately above and within 100 feet of the known extent of the free product plume. The detection of vapors at concentrations equal to or greater than 10 percent of the LEL of any one of the volatile components of the free product shall constitute a potential explosion hazard and shall require abatement. Refer to Table 6-3 for a listing of the LELs and 10% LELs of various volatile petroleum components.

6.8.2 Free Product Plume Shall be Fully Delineated

The occurrence of free product petroleum must be documented and investigations must be conducted to determine the extent of the free product and whether and to what extent it is migrating. This determination will require the installation of a number of borings and monitoring wells sufficient to fully define the free product and periodic measurement of free product in these wells. The resulting data must be sufficient to demonstrate spatial and temporal trends in free product thickness. Note that free product thickness is critically affected by water table fluctuations. Therefore, the collection of sufficient data, especially at sites where there are strong seasonal and long-term water table fluctuations, is very important to ensure accurate delineation and characterization.

6.8.3 Free Product Tiered Risk Assessment

Free product can pose a direct risk to human health via, for instance, vapor migration or direct contact. The risk free product poses to human health and the environment depends, in part, on the dissolved and vapor phase concentrations associated with the free product. These concentrations, in turn, depend on the composition of the free product. For a Tier 1 risk assessment, the default free product composition values shown in Table 5-2 are used to estimate the dissolved and vapor phase concentrations associated with free product at a site. To accurately evaluate free product at Tier 1 requires that the evaluator know the specific type of free product present at his or her site (e.g., gasoline, diesel fuel, etc.). If the free product is composed of more than one type of petroleum, all applicable values from Table 5-2 must be used. The specific equations used to calculate the values in Table 5-2 are presented in Appendix B.

For a Tier 2 risk assessment, a sample of the free product at the site can be used to determine the mole fraction of the various COCs comprising the free product and these site-specific values can be used to evaluate risk. In the absence of such site-specific values, default values from Table 5-2 may be used at Tier 2 with adequate justification. At Tier 3, alternate technically defensible methods and models to evaluate free product, whether as to composition, fate and transport, or plume stability, may be proposed in the work plan and used upon approval by MDNR.

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6.8.4 Free Product Plume Stability

The stability of the free product plume must be evaluated. The outcome of such an evaluation will, in part, dictate whether and to what extent continued free product recovery is required. Refer to Section 5.9.3 of this document for information regarding demonstrations of plume stability.

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6.8.5 Practicability of Free Product Removal

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Free product must be removed from the environment to the maximum extent practicable. The degree of removal constituting the "maximum extent practicable" is a site-specific determination and does not equate to a generic "free product thickness in well" measurement that can be uniformly applied to all sites.

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6.9 ACTIVITY AND USE LIMITATIONS

AULs can be used, when appropriate, in conjunction with, or instead of, active remediation methods in managing risk at UST/AST sites. AULs will generally be used when residual COCs will remain on a site following an evaluation of risk. AULs are applied for a variety of reasons that include (ASTM, 2000):

- To eliminate certain pathways of exposure, e.g. an AUL that prevents the construction of a structure on a portion of a site may eliminate the need to evaluate the indoor inhalation exposure pathway;
- To ensure that information about past corrective action activities and the presence of residual chemicals on the property is readily available to all current and future interested parties (e.g. owners, tenants, lenders, etc.);

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- To identify, for the benefit of all current and future interested parties, any restrictions on the use of the property, e.g., if the property has been cleaned for non-residential use, AULs shall specify that residential development of the site be restricted;
- To identify for the benefit of current and future interested parties the types of activities that may be conducted without resulting in unacceptable risk,
- Identify any long term operation and maintenance obligations, e.g. if a vapor barrier or ventilation system has been constructed under a building, an AUL might identify periodic maintenance and operation requirements. In such cases, the AUL will identify the entity responsible for these obligations.
- AULs may provide a right of entry to MDNR or others to allow for, for instance, inspection of AUL provisions or the performance of any future on-site activities that may be necessary, e.g. access to monitoring wells and the ability to install additional wells, if necessary.

MDNR's AUL policy for the MRBCA process is found at Section 11 of this document.

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with groundwater containing LNAPL. LNAPL also poses indirect risks to human health and the environment via, for instance, contaminant dissolution into groundwater.